CLAIMS

What is claimed is:

1. An apparatus for determining at least one dimensional value of a substantially planar substrate, comprising:

a carrier configured for holding and positioning a substantially planar substrate having first and second opposed surfaces in a plane;

a first linear measuring device including a first movable caliper finger disposed on one side of the plane for measuring a first linear distance from a zero point to the first surface of the substrate along an axis substantially normal to the first and second surfaces;

a second linear measuring device including a second movable caliper finger disposed on an opposing side of the plane for measuring a second linear distance from the zero point to the second surface of the substrate along the axis generally normal to the first and second surfaces, the second movable caliper finger being coaxial with the first movable caliper finger; and

a calculation device for calculating the first and second linear distances.

2. The apparatus of claim 1, wherein the first and second movable caliper fingers each include terminal contact members for contacting the respective first and second surfaces of the substrate.

3. The apparatus of claim 2, wherein the first and second linear measuring devices are configured to provide a zero point value as a linear distance for each of the first and second movable caliper fingers with the terminal contact members in axial contact with each other for use by the calculation device in calculating the first and second linear distances.

4. The apparatus of claim 2, wherein the contact members comprise one of smooth-surfaced enlargements at the terminal ends of the caliper fingers, unidirectional rollers and multidirectional roller balls.

5. The apparatus of claim 1, wherein the first movable caliper finger and the second movable caliper finger are each biased toward the plane.

6. The apparatus of claim 1, wherein the carrier is configured to move the substrate within the plane between the first and second movable caliper fingers.

7. The apparatus of claim 6, wherein the carrier is configured to move the substrate in at least one direction parallel to the plane.

8. The apparatus of claim 7, wherein the carrier is configured to move the substrate in a plurality of directions within the plane.

9. The apparatus of claim 7, wherein the apparatus is configured to measure the first linear distance and the second linear distance from the zero point in at least three different locations on the first and second surfaces of the substrate in association with movement of the substrate by the carrier in the at least one direction.

10. The apparatus of claim 9, wherein the calculation device is configured to determine at least one warpage characteristic of the substrate from at least some of the measurements at the at least three different locations.

11. The apparatus of claim 8, wherein the apparatus is configured to measure the first linear distance and the second linear distance from the zero point in at least three different locations on the first and second surfaces of the substrate in association with movement of the substrate by the carrier in the plurality of directions.

12. The apparatus of claim 11, wherein the calculation device is configured to determine at least one warpage characteristic of the substrate from some of the at least three first and second linear distance measurements.

13. The apparatus of claim 7, wherein the carrier is configured to move the substrate continuously between the first and second movable caliper fingers while in contact therewith.

14. The apparatus of claim 13, wherein the calculation device is configured to determine at least one warpage characteristic of the substrate from at least some of a plurality of first and

second linear distance measurements taken along a line of contact with the substrate by the first and second movable caliper fingers.

15. The apparatus of claim 1, wherein the carrier comprises a robotic gripper.

16. The apparatus of claim 1, wherein the first and second linear measuring devices comprise linear encoders, linear potentiometers or linear displacement transducers.

17. An apparatus for determining at least one dimensional value of a substantially planar substrate, comprising:

at least one complementary set of linear measuring devices including movable caliper fingers, each of the at least one set comprising:

first and second coaxial, opposing, movable caliper fingers with mutually facing terminal ends;

structure for biasing each of the first and second coaxial, movable caliper fingers toward one another;

a first contact member on the terminal end of the first caliper finger;

a second contact member on the terminal end of the second caliper finger;

wherein the at least one complementary set of linear measuring devices is configured to provide a zero point value as a linear distance for each movable caliper finger with contact members of the first and second coaxial, opposing, movable caliper fingers in mutual contact defining a zero point and to provide displacement values for each movable caliper finger when displaced away from the zero point;

a carrier for holding, positioning and moving a substantially planar substrate in at least one direction parallel to a plane perpendicular to the movable caliper fingers of the at least one complementary set of linear measuring devices to pass the substantially planar substrate therebetween; and

a device for receiving zero point values and displacement values and calculating at least one dimensional value associated with the substantially planar substrate.

18. The apparatus of claim 17, wherein the carrier is configured to move the substantially planar substrate parallel to the plane either continuously or discontinuously.

19. The apparatus of claim 17, wherein the device for receiving zero point values and displacement values and calculating at least one dimensional value associated with the substantially planar substrate comprises a computer and further comprises memory and at least one output device for storage and expression of the at least one dimensional value.

20. The apparatus of claim 17, wherein the carrier comprises a robotic gripper.

21. The apparatus of claim 17, wherein the contact members comprise smooth-surfaced enlargements at the terminal ends of the movable caliper fingers, unidirectional rollers or multidirectional roller balls.

22. The apparatus of claim 17, wherein the apparatus is configured to cause the linear measuring devices to provide displacement values from the zero point value in at least three different locations on the substantially planar substrate responsive to movement of the substantially planar substrate in the at least one direction.

23. The apparatus of claim 22, wherein the device for receiving zero point values and displacement values and calculating at least one dimensional value associated with the substantially planar substrate is configured to determine at least one warpage characteristic of the substantially planar substrate from at least some of the displacement values for the at least three different locations.

24. The apparatus of claim 17, wherein the carrier is configured to move the substrate in a plurality of directions parallel to the plane.

25. The apparatus of claim 24, wherein the apparatus is configured to cause the linear measuring devices to provide displacement values from the zero point value in at least three different locations on the substantially planar substrate responsive to movement of the substantially planar substrate in the plurality of directions.

26. The apparatus of claim 25, wherein the device for receiving zero point values and displacement values and calculating at least one dimensional value associated with the

substantially planar substrate is configured to determine at least one warpage characteristic of the substrate from at least some of the displacement values for the at least three different locations.

27. The apparatus of claim 17, wherein the carrier is configured to move the substantially planar substrate continuously between the movable caliper fingers while in contact therewith.

28. The apparatus of claim 27, wherein the device for receiving zero point values and displacement values and calculating at least one dimensional value associated with the substantially planar substrate is configured to determine at least one warpage characteristic of the substantially planar substrate from at least some of a plurality of displacement values taken along a line of contact with the substantially planar substrate by the movable caliper fingers.

29. The apparatus of claim 17, wherein the linear measuring devices comprise linear encoders, linear potentiometers or linear displacement transducers.

30. The apparatus of claim 17, wherein the at least one set of complementary linear measuring devices comprises a plurality of sets of complementary linear measuring devices.

31. The apparatus of claim 30, wherein the plurality of complementary sets of linear measuring devices are mutually spaced along the plane transversely to a direction of intended movement of the substantially planar substrate by the carrier.

32. A method for determining at least one dimensional value of a substantially planar substrate,

comprising:

establishing a plane parallel to which a substantially planar substrate is to be disposed;

establishing a zero point location in or immediately adjacent the plane from which first and second opposing linear distances perpendicular to the plane may be measured;

placing the substantially planar substrate parallel to the plane and with the zero point location located within the substantially planar substrate; and

measuring the first and second opposing linear distances from the zero point location to each of two opposing sides of the substantially planar substrate in at least one location on the substantially planar substrate.

33. The method of claim 32, further comprising determining a thickness of the substantially planar substrate by adding the measured first and second opposing linear distances.

34. The method of claim 32, wherein the at least one location comprises a plurality of predetermined locations.

35. The method of claim 34, further comprising determining any warpage of the substantially planar substrate by comparing differences in at least some of the opposing, measured first and second linear distances from the zero point locations at different locations of the plurality of predetermined locations.

36. The method of claim 35, further comprising determining any warpage of the substantially planar substrate by comparing differences in measured first linear distances from the zero point location at the different locations of the plurality of predetermined locations.

37. The method of claim 34, further comprising selecting at least some of the predetermined locations of the plurality to be spaced along a longitudinal extent of the substantially planar substrate.

38. The method of claim 37, wherein the at least some predetermined locations spaced along a longitudinal extent of the substantially planar substrate are selected to be adjacent a longitudinal edge of the substantially planar substrate.

39. The method of claim 37, further comprising selecting at least one other location of the plurality on the substantially planar substrate to be spaced laterally from the at least some of the predetermined locations.

40. The method of claim 34, wherein the plurality of predetermined locations comprises a substantially continuous path extending across at least a portion of the substantially planar substrate.

41. The method of claim 32, further comprising measuring the first and second linear distances by measuring displacements of first and second opposing elements in contact with the opposing sides of the substantially planar substrate.

42. The method of claim 41, further comprising establishing the zero point location as a location of mutual contact of the first and second opposing elements without interposition of the substantially planar substrate therebetween.

43. The method of claim 42, further comprising biasing the first and second opposing elements toward mutual contact.

44. The method of claim 43, further comprising passing the substantially planar substrate between the first and second opposing elements while measuring the displacements thereof on a plurality of predetermined locations on the substantially planar substrate.